Client ref:88036/2001-2-19
Our File:0178-5019USF/ycchen/nelson

THIN-FILM DESIGN FOR OPTICAL RECORDING MEDIA

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention is related to optical recording media. More specifically, the present invention is related to a thin-film optical recording medium and compatible materials that achieve high-density, high-resolution, high-speed recording of data, and are highly compatible with the full visible-light spectrum.

Description of the Related Art

Optical recording media has the advantage of easy recording and long-lasting data storage. Optical recording media is widely used in electronic publishing, multi-media data storage, and massive file-backup.

The structural components of conventional optical recording media include a substrate, a reactive layer, a reflecting layer and a protective layer, wherein the reactive layer is the primary recording element.

Typically, the reactive layer is made of organic dye. However, a reactive layer that is made of organic dye has disadvantages. First, organic dye can be easily degraded by environmental light exposure that results in a shortened product shelf life before recording. Second, the use of organic dye for optical recording media is less promising in future high-density optical-recording demands. Third, organic-dye formulation reacts within a narrow optical bandwidth and records with a specific wavelength of light

source in a particular optical-recording system. Finally, production of organic dye requires organic solvents that might result in a certain level of environmental contamination.

Prior art (for example, JP Pat. No. 6-171236) discloses an inorganic optical recording medium with an Al/Au reflecting layer and a Ge reactive layer. The reflectivity of the design can be raised as high as 70%; however, the optical contrast after recording can only be elevated, not lowered, making it incompatible with the specifications of signal modulation of current optical recording media, and thus limiting its applications.

U.S. Pat. No. 5,458,941 discloses a reflecting layer consisting of Au-Cr, Au-Co, or Al-Ti and a reactive layer consisting of semiconductor materials. The reflecting layer is deposited on the incident side of the recording light beam to increase the reflectivity. However, this design requires higher recording power levels and thus limits its applications.

Recently, JP Pat. No. 08-274809 disclosed a recording layer consisting of a semiconductor layer and a reflecting metallic layer that can produce semiconductor/metal contacts inducing crystalline effect during light exposure. The amorphous semiconductor layer (the reacting layer, such as Si) will crystallize starting from the semiconductor/metal (such as Si/Al) interface which results in the modulation of the reflectivity of the recording layer. However, the signal modulation resulting from the amorphous/crystalline transformation is small and limited thereby limits the design's applicability to the diverse specifications of optical recording media.

Indeed, neither the inorganic materials type nor the organic dye type optical recording media of the conventional art can fulfill future demands for a high-density recording within the full visible-light range.

SUMMARY OF THE INVENTION

The objective of the present invention is to provide a thin-film optical recording medium and compatible materials able to achieve high-density, high-resolution, high-speed recording of data. It is another object of the present invention to provide a thin-film optical recording medium and compatible materials highly compatible with the full visible-light spectrum.

To accomplish the above, the optical recording medium of the present invention is at least composed of a substrate, a transparent layer, and a reflecting layer. The present invention utilizes a light beam to heat the transparent layer and the reflecting layer, thereby forming a semi-transparent reflective area that is an alloy and/or compound of the transparent layer and the reflecting layer by means of an alloy/compound reaction. The alloy/compound reaction requires a minimum power-density threshold. The semi-transparent reflective area achieves the following effects: (1) reducing the effective thickness of the transparent layer and altering the respective optical path lengths, resulting in a shift of constructive or destructive interference patterns; and/or (2) transforming the optical constants (n & k) and thus the reflective intensity; and/or (3) altering the polarization angle. At least one of the above effects constitutes the mechanism that produces optical contrast before and after recording.

The thin-film optical medium and compatible materials disclosed in the present invention are therefore capable of (1) recording within the full visible-light range; (2) high-density recording; (3) high-speed recording; (4) high-definition recording; and (5) recording with a high degree of compatibility with diverse optical recording media formats.

The reasons are as follows: (1) The selected metal or alloys of the reflecting layer reflects light with sufficient intensity and can react with the selected materials of the transparent layer to create a semi-transparent reflective area at any wavelength within the full visible-light range such that an optimum optical contrast level can be achieved. Hence, the optical-recordable media of the present invention is suitable for a wide spectrum of recording light; (2) The reaction that generates the semi-transparent reflective area requires a distinctive threshold energy density, and only upper part of the laser beam (Gaussian distribution) is effective for forming the recording, resulting in much smaller recorded marks than the writing laser footprint, and therefore high-recording density can be achieved; and (3) Both atoms of reflecting layer and transparent layer diffuse only few hundreds of Angstroms to form the semi-transparent area, and this reaction is much faster than that in recording a dye-based recordable media or in recording a phase-change type rewritable media. Therefore, the optical disc in the present invention is suitable for high speed recording; (4) The reaction that generates the semi-transparent reflective area requires a distinctive threshold energy density, which results in a sharp and clear border for the semi-

transparent reflective area and produces high- definition recording marks; (5) The recording power can be easily adjusted by selecting suitable materials for the reflecting layer, so that the optical recording medium of the present invention can accommodate recording-power requirements of various optical recording media.

Further, the thin-film optical medium and compatible materials of the present invention are capable of recording at a wide range of wavelengths and applicable to not only the CD systems or the developing DVD systems but also the future blue-light wavelength optical-recording systems. Furthermore, due to the minimum power density threshold requirement for the recording and the short time period of diffusion for the formation of recording mark, the recorded marks can be very small and quickly formed, making them superior for high-speed and high-density optical recording applications.

Another advantage of the present invention is that it provides a thin-film optical recording medium generating an optical reflective contrast that can be compliant with or counter to the current compact disk systems broadening the scope of its application. In addition, since the inorganic materials used in the present invention initiate reactions only above a threshold light intensity level, the thin-film design is insensitive to the general ambient lights and is therefore more optically stable and less apt to deteriorate compared to the dye-based recordable media.

Finally, the use of inorganic materials in the present invention eliminates the need for organic solvent(s), thus reducing environmental impact.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described in detail with references to the illustrated embodiments and accompanying drawings, in which:

Fig. 1A is a schematic drawing showing the structure of an optical recording medium of the present invention with a thermal-manipulating layer.

Fig. 1B is a schematic drawing showing the structure of an optical recording medium of the present invention without the thermal-manipulating layer.

Fig. 2A is a schematic drawing showing the altered structure (with the thermal-manipulating layer) after writing the optical recording medium of the present invention with a light beam.

Fig. 2B is a schematic drawing showing the altered structure (without the thermal-manipulating layer) after writing the optical recording medium of the present invention with a light beam.

Fig. 3 is an optical micrograph taken after performing the static test in Embodiment 1.

Fig. 4 is an optical micrograph taken after performing the static test in Embodiment 2.

Fig. 5 is an optical micrograph taken after performing the static test in Embodiment 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to Figs. 1A and 1B, the process of manufacturing an optical recording medium begins with a substrate 10. Substrate 10 can be made of glass or

polycarbonate. An optional first thermal-manipulating layer 20 for either speeding or slowing thermal conduction may be formed on substrate 10 to control the writing power. Then, a transparent layer 30 is deposited, the thickness of which is about 5 to 500 nm. The transparent layer 30 can be selected from the group of material(s) consisting of Si, Ge, GaP, InP, GaAs, InAs, GaSb, InSb, In-Sn oxide, tin oxide, indium oxide, zinc oxide, titanium oxide, Sb-Sn oxide, and/or combinations thereof.

Next, the reflecting layer 40 is formed on the transparent layer 30. The thickness of the reflecting layer 40 is about 1 to 500 nm. The reflecting layer 40 can be selected from the group of material(s) consisting of Ag, Al, Au, Pt, Cu, In, Sn, W, Ir, Re, Rh, Ta, alloys, and/or combinations thereof.

The individual thickness and chemical compositions of the transparent layer 30 and the reflecting layer 40 are selected such that, when heated by a light beam, the transparent layer 30 and the reflecting layer 40 will react to form a semi-transparent reflective area 35 (as shown in Figs. 2A and 2B). The chemical composition of the semi-transparent reflective area is an alloy and/or compound of the transparent layer 30 and the reflecting layer 40. The presence of the semi-transparent reflective area 35 (the recorded mark) produces an optical reflecting contrast against the non-recorded area of the reflecting layer.

The optical reflecting contrast produced by the presence of the semi-transparent reflective area 35 leads to signal modulation within the full visible-light range from at least one of the following effects: (1) As a result of the

alloy/compound effect, the semi-transparent reflective area 35 changes the optical constants (n & k) in the area thus altering the overall reflectivity; (2) The presence of the semi-transparent reflective area 35 reduces the effective thickness of the transparent layer 30 and alters the respective optical-path lengths thereby shifting constructive or destructive interference; and (3) Due to the alloy/compound effect, the semi-transparent reflective area 35 changes the polarization angle thus altering the intensity read by the polarization optics.

Subsequently, an optional second thermal-manipulating layer 50 for either speeding or slowing thermal conduction may be formed on substrate 10 to control the writing power. Finally, a protecting layer 60 is deposited either on the reflecting layer 40 or on the optional second thermal-manipulating layer 50. The resulting structure is shown in Figs. 1A and 1B, where Fig. 1A is a schematic drawing showing the structure with thermal-manipulating layers and Fig.1B is the schematic drawing showing the structure without thermal-manipulating layers. Depending on the combinations of the transparent layer 30 and the reflecting layer 40, the thin-film design may or may not include thermal-manipulating layers.

Embodiments of the present invention show that, by varying the thickness of the effective transparent layer 25 of the transparent layer 30, the manner of signal modulation can be changed. When the thickness is greater than a specific value or less than another specific value, the manner of signal modulation can be switched from one where the pre-recording reflectivity is greater than that of the recorded,

to another where the pre-recording reflectivity is lower than that of the recorded. The inverse is also possible.

<u>Embodiment 1</u>

In this embodiment, an optical recording medium was prepared by magnetron-sputtering a silicon target on a glass substrate 10 to form a transparent layer 30. The sputtering power was set at 300W and the sputtering time was 30 minutes. A reflecting layer 40, deposited next, was an Au-Si alloy wherein Au was sputtered at a power of 260W and Si was sputtered at a power of 210W for 30 minutes. The resulting structure is shown in Figs. 1A and 1B.

To test the recording performance for the optical recording medium, a static tester was used. The static tester uses a laser diode of 780 nm wavelength that requires a 21 mA DC current for reading signals and the DC current further superimposes 1~5V pulses for writing marks (the shortest write-pulse being 10 ns). The optical system is similar to that of the CD system, except that the diameter of the light beam is greater than that of the CD system.

Fig. 3 is an optical micrograph of recorded marks after the static test. The micrograph shows that the semi-transparent reflective area 35 (the recorded marks being about 2 μm in diameter) has distinct boundary even with superimposed 3V pulses on 21mA DC current with pulse duration down to 10ns. The optical contrast of the recording is 85%. The optical contrast is defined as (Io-Iwr)/Io´100% wherein Io is the pre-recording reflectivity and Iwr is the reflectivity of the recorded marks. Applying the same test conditions to the commercial CD-R,

the size of the recorded mark is around 16 μm in diameter and the optical contrast is 50%.

Embodiment 2

In this embodiment, an optical recording medium was prepared by magnetron-sputtering a silicon target on a glass substrate 10 to form a transparent layer 30. The sputtering power was set at 300W and the sputtering time was 10 minutes. The reflecting layer 40, deposited next, was an Au-Si alloy wherein Au was sputtered at a power of 260W and Si was sputtered at a power of 210W for 30 minutes. The resulting structure is shown in Figs. 1A and 1B.

Fig. 4 is an optical micrograph of recorded marks after the static test. The test conditions are the same as that of Embodiment 1. Fig. 4 indicates that the reflectivity of semi-transparent reflective area 35 is raised when applying 3V pulses superimposed on a 21mA DC current at all pulse duration. The greatest optical contrast achieved was -45percentage. The smallest size of the recorded marks achieved was 2.0 μm.

Embodiment 3

In this embodiment, optical recording media specimens were prepared individually by magnetron-sputtering a silicon target on a glass substrate 10 to form a transparent layer 30. The sputtering power was set at 300W and the sputtering times were 5, 10, 15, 20, 25, 30, 35 and 40 minutes respectively. A reflecting layer 40, deposited next, was Au-Si alloy where Au was sputtered at powers of 50, 110, 180, 240, 300, 370, 440, and 500W and Si was

sputtered at a power of 210W. The resulting structure is shown in Figs. 1A and 1B. There is no protecting layer. The test conditions of the static tests followed were the same as those in Embodiment 1.

Summarizing the reflectivity measurements of all specimens in this embodiment, the reflectivities in wavelength range from 300nm to 900nm are between 5 to 90%. Table 1 shows the highest and lowest reflectivity of this embodiment at respective wavelengths and reveals that the optical recording medium of the present invention retains high reflectivity within the full visible-light range.

Table 1

Wavelength (nm)	780	650	400
Highest Reflectivity (%)	55	62	37
Lowest Reflectivity (%)	8	14	24

Table 2 illustrates the largest optical contrast (positive and negative) resulting from all possible combinations of the transparent layer and the reflecting layer in this embodiment at optical wavelengths 780nm, 650nm, and 400nm. Table 2 shows that the optical recording medium of the present invention have sufficient optical contrast within the full visible-light range for signal modulation that is either compliant with or counter to the concurrent compact disk systems, where positive optical contrast is compliant with the signal modulation of the concurrent compact disk systems while negative optical contrast is counter to the concurrent system.

Table 2

Wavelength (nm)	780	650	400
Positive Contrast (%)	85	80	50
Negative Contrast (%)	-90	-	-50
		100	

Embodiment 4

In this embodiment, four samples were prepared by magnetron-sputtering on a polycarbonate (PC) substrate 10 with a layer sequence of PC/$(ZnS.SiO_2)_1$/Si/(Si-Au)/$(ZnS.SiO_2)_2$. Sample 1 contained no $(ZnS.SiO_2)_1$and $(ZnS.SiO_2)_2$, sample 2 contained no $(ZnS.SiO_2)_1$, and sample 3 contained no $(ZnS.SiO_2)_2$.

The sputtering power for Si (transparent layer 30) was set at 300W and the sputtering time is 30 minutes. The sputtering power for $ZnS.SiO_2$ (the first and the second thermal-manipulating layer 20 and 50) was set at 300W and the sputtering time is 30 minutes. A reflecting layer 40 (Au-Si alloy) was co-sputtered at a power of 260W for Au and was sputtered at a power of 210W for Si for 30 minutes.

The static test conditions were the same as that of Embodiment 1. Fig. 5 is an optical micrograph taken after the static test of sample 1. The micrograph shows that the reflectivity of the semi-transparent reflective area 35 is decreased when applying 2V pulses superimposed on a 21mA DC current at all pulse duration.

When superimposing 2V pulses at all pulse duration, the sizes of the semi-transparent reflective area 35 appeared to be below 1.5 μm. The optical contrasts before and

after the recording are between 51% and 70%. The smallest size is under 1.5 μm with 10ns writing pulse duration while the optical contrast before and after the recording reaches 51%.

When superimposing 3V pulses, the largest optical contrast can reach 100% and the smallest size can be 2.0 μm.

Similar results could be obtained for recording sample 2 to 4. However, for sample 2 and 3 no recorded mark was observed as the writing pulse duration was lower than 100 ns for 2 V writing pulse, and the value was 200 ns/2V for sample 4. It is clear that the optimum writing strategy can be changed by adding the thermal-manipulating layer 20 and/or 50 (ZnS.SiO2).

Embodiment 5

In this embodiment, an optical-recording media was prepared by magnetron-sputtering an In-Sn oxide target onto a glass substrate 10 to form a transparent layer 30 of about 50 nm in thickness. A reflecting layer 40, deposited next, was Sn. The resulting structure is shown in Figs. 1A and 1B.

Static test conditions were the same as that of Embodiment 1. The results show that the reflectivity of the semi-transparent reflective area 35 is decreased when applying more than 1V pulses superimposed on a 27mA DC current at all pulse duration.

When superimposing 2V pulses, the sizes of the semi-transparent reflective area 35 are below 1.5 μm. The optical contrasts before and after the recording are between 30% and 60%. The smallest size is under 1.5 μm with 10ns writing pulse duration while the optical contrast before and after the recording reaches 48%.
When superimposing 3V pulse, the greatest optical contrast can reaches 60%.

Although the present invention has been disclosed by a limit number of embodiments shown above, it should be understood that the present invention is not limited to the disclosed embodiments for any person who are skilled in the arts of the present invention could make various modifications or similar arrangements that are possible without departing from the principles and spirit of the present invention. Therefore, the scope of the appended claims and their equivalents should be accorded the broadest interpretation to encompass all such modifications and similar arrangements.